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DESIGN AND DEVELOPMENT OF ELECTRICAL AND MECHANICAL INSTRUMENTS FOR THE AURORAL-E PROGRAM

Peter B. Anderson
Donald Girouard

Regis College
235 Wellesley Street
Weston, Massachusetts 02193

1 May 1981

Scientific Report No. 1

Approved for public release; distribution unlimited

AIR FORCE GEOPHYSICS LABORATORY
AIR FORCE SYSTEMS COMMAND
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Electrometer Amplifiers

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The Auroral-E program consisted of four rocket payloads which were launched from the Poker Flat Research Range in Alaska. This report covers the design and development of the electric field and electron density experiment instrumentation.

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Preface

We wish to acknowledge Robert E. Shupe for providing engineering services on this contract. This work was done under Air Force Geophysics Laboratory contract F19628-80-C-0116.

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1. INTRODUCTION

The Auroral E-Program consisted of four rocket payloads which were launched from the Poker Flat Research Range, Fairbanks, Alaska, on March 6, 1981. This report describes the engineering activities carried out during the development of the A10.903 payload. The payload experiment consisted of a double-probed electric field instrument to measure ac and dc electric fields, a density strip for measuring electron densities, and an automatic gain control (AGC) unit. A block diagram of this experiment is shown in Figure 1.

2. OBJECTIVES

Auroral-E Program objectives were to obtain in-situ measurements of several atmospheric and ionospheric parameters during a continuous diffuse aurora. Other goals of the rocket program were to have nearly simultaneous measurements of the energy and angular distrubution of electron and proton flux, optical emissions from atomic and molecular atmospheric constituents, ion species, electron densities, neutral and mass densities, neutral and electron temperatures, neutral winds and electric fields. The rocket measurements were also coordinated with passes of a satellite which provided precipitating electron and proton measurements. The AFGL Airborne Ionospheric

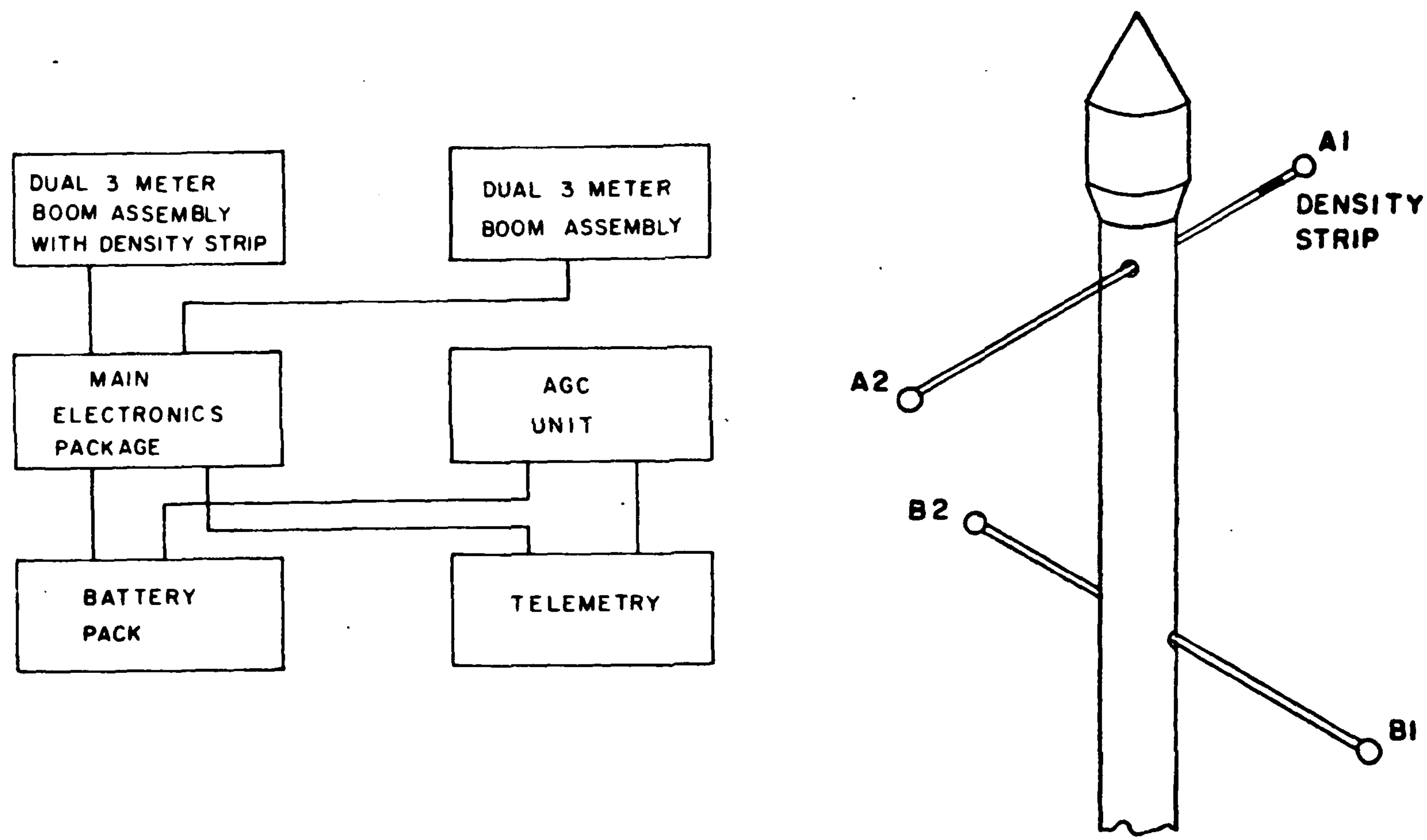


Figure 1 System Block Diagram

Observatory made passes near each rocket launch and measured auroral optical emissions as well as ionospheric parameters. In addition, ground-based measurements of electron density profiles in the region of the rocket trajectories were provided by the Chatanika Radar Site.

3. INSTRUMENTATION

3.1 BACKGROUND

Instrumentation for the Electric Field experiment consisted of a flight system and two ground support equipment (GSE) consoles. The flight system consisted of a main electronics package (MEP), two 3-meter boom assemblies, and an automatic gain control (AGC) unit. These flight units are shown in Figures 2, 3, and 4 respectively. In flight, the method of measurement was to deploy the two mutually perpendicular dipoles (3-meter boom assemblies) normal to the rocket spin axis with a separation of $57\frac{3}{4}$" between the fore and aft dipoles. These perpendicular dipoles were deployed at T+60 seconds (80 KM) slowing the spin rate from 5.5 rps to 3.8 rps. The mutual potential differences between pairs of spherical sensors ($1\frac{3}{8}$" diameter) mounted at the dipole tips, with a 3-meter separation, yield the vector electric fields These field signals were processed by the MEP and AGC units as shown in the electrical block diagram, Figure 5. Also, a conducting strip, located near the A1 spherical sensor, yielded

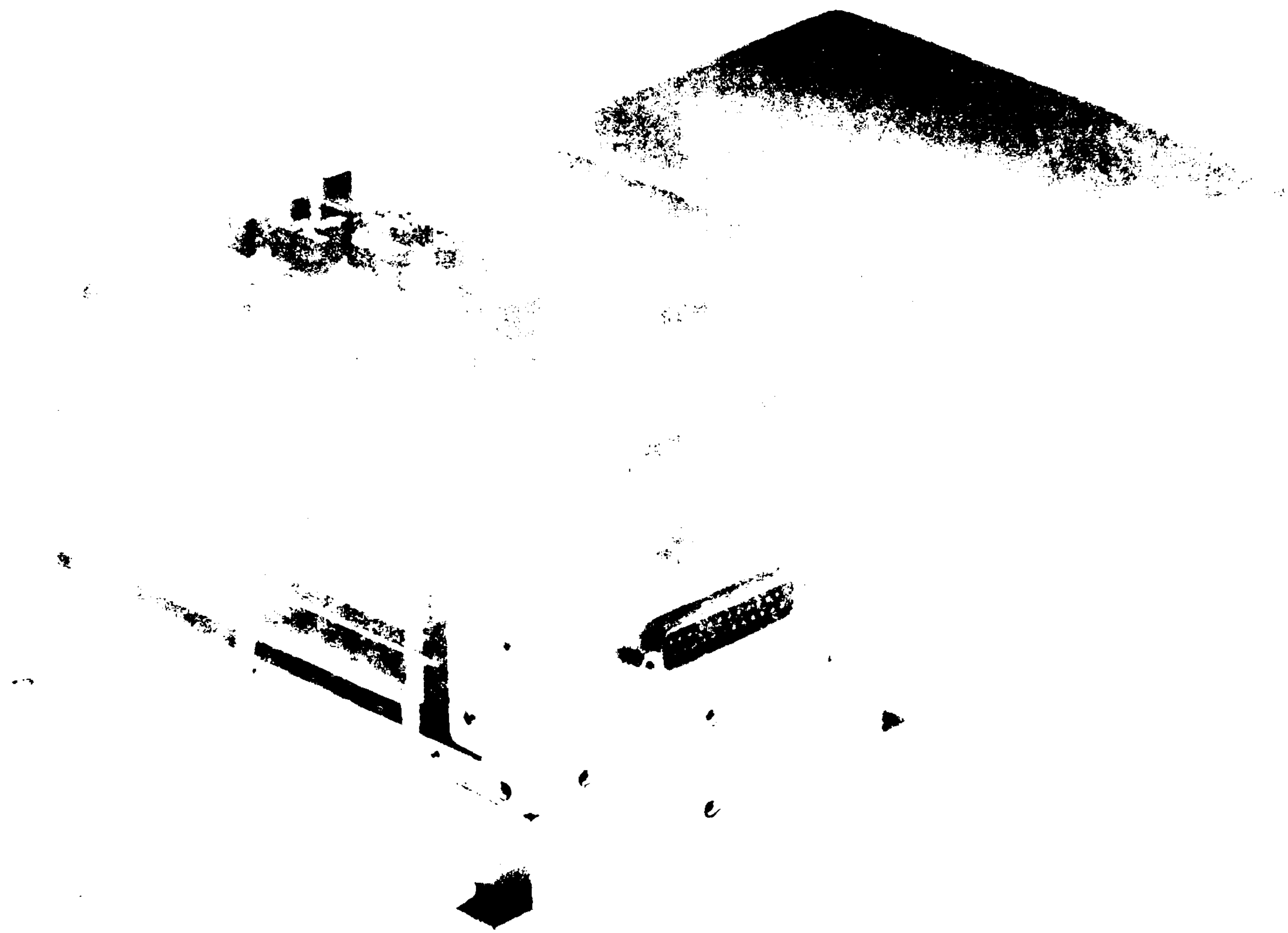


Figure 2 Main Electronic Package

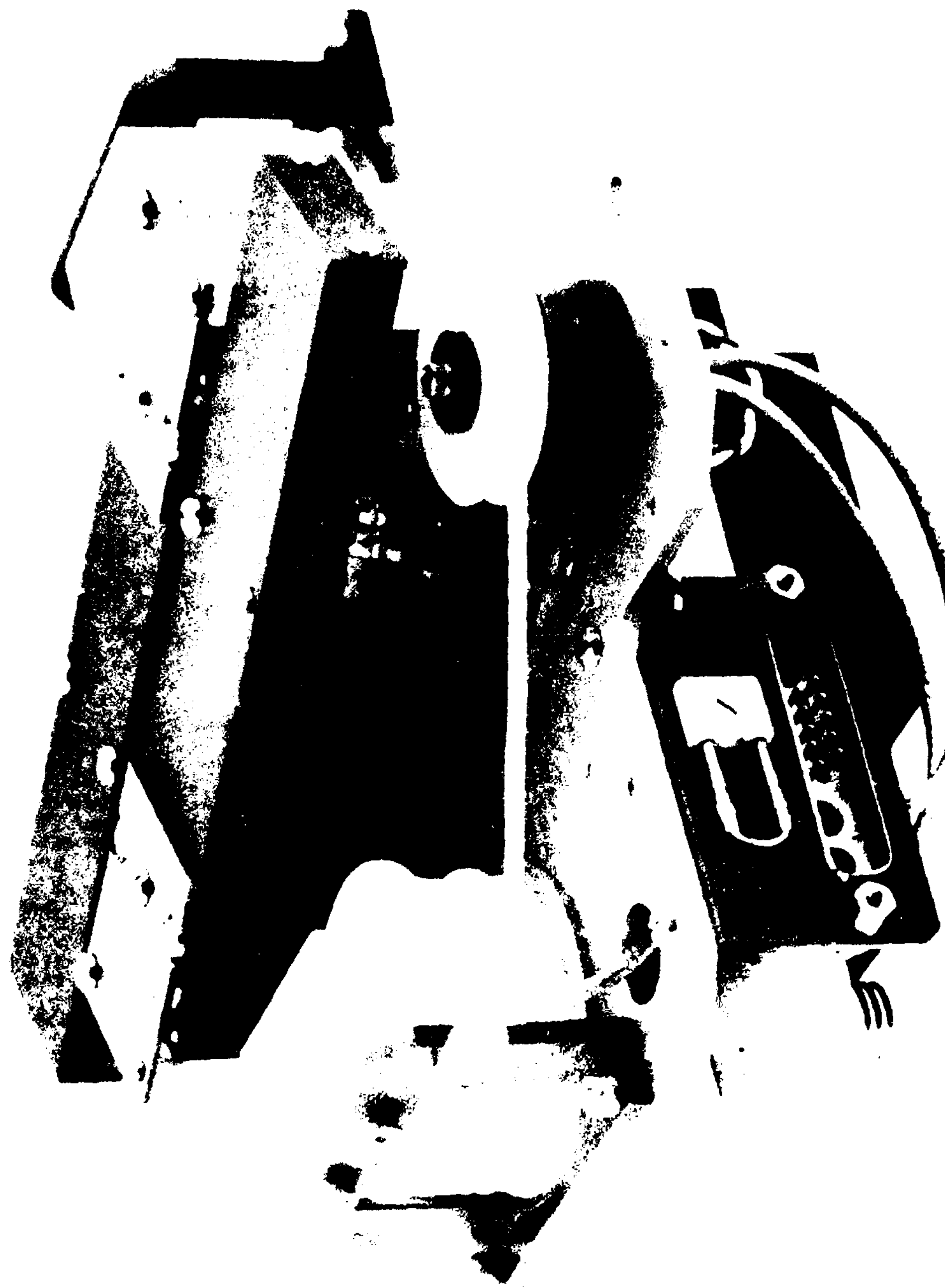


Figure 3 3-Meter Boom Assembly

Figure 4   Automatic Gain Control Unit

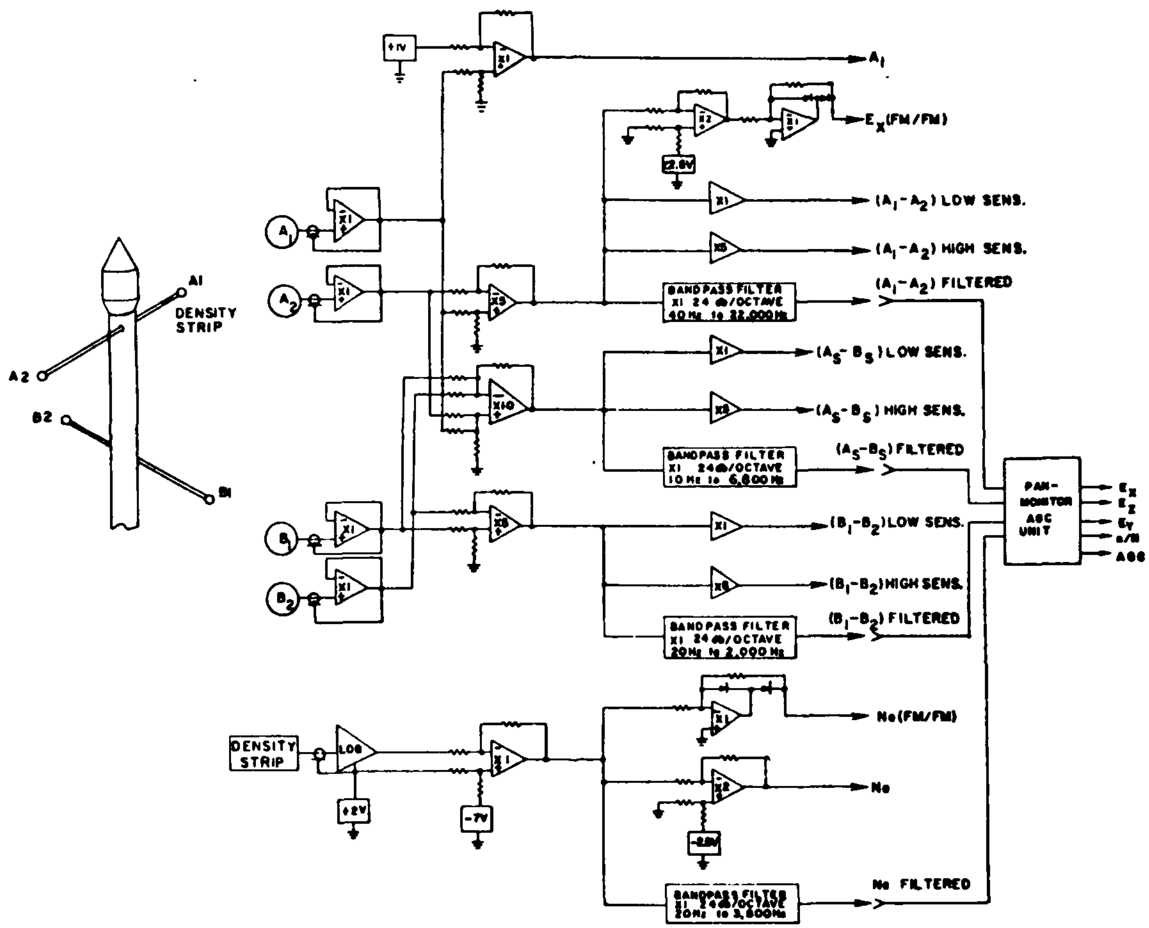


Figure 5 Electrical Block Diagram

the electron signal for the density measurement. This signal was also processed by the MEP and AGC units.

The GSE units were used for initial debugging, burn-in calibration and payload integration. One unit was a passive chassis for interfacing the MEP, the test equipment, and the AGC unit, with the input signals plus power. The other GSE unit (called the AGC console) received a serial digital data line from the AGC unit and displayed its content. This AGC console is shown in Figure 6.

3.2 3-METER BOOM ASSEMBLY

The procurement of the two 3-meter boom assemblies was accomplished under another AFGL contract. However, flight preparation work was done under this contract. The electrical connections were wired to the interface connectors. Also, a special removal tool was designed and fabricated for removing the $1\frac{3}{8}$" diameter spherical sensors. The sensors were mounted on the boom assemblies with 12 in-lbs of torque for integration and vibration tests. Then the sensors were removed for shipping using the special tool. At the launch site, the spheres were sand blasted with a fine grit and then coated with 3 coats of Aerodag G. Just prior to the rocket skin being installed for the last time, the sensors were then installed again with 12 in-lbs of torque.

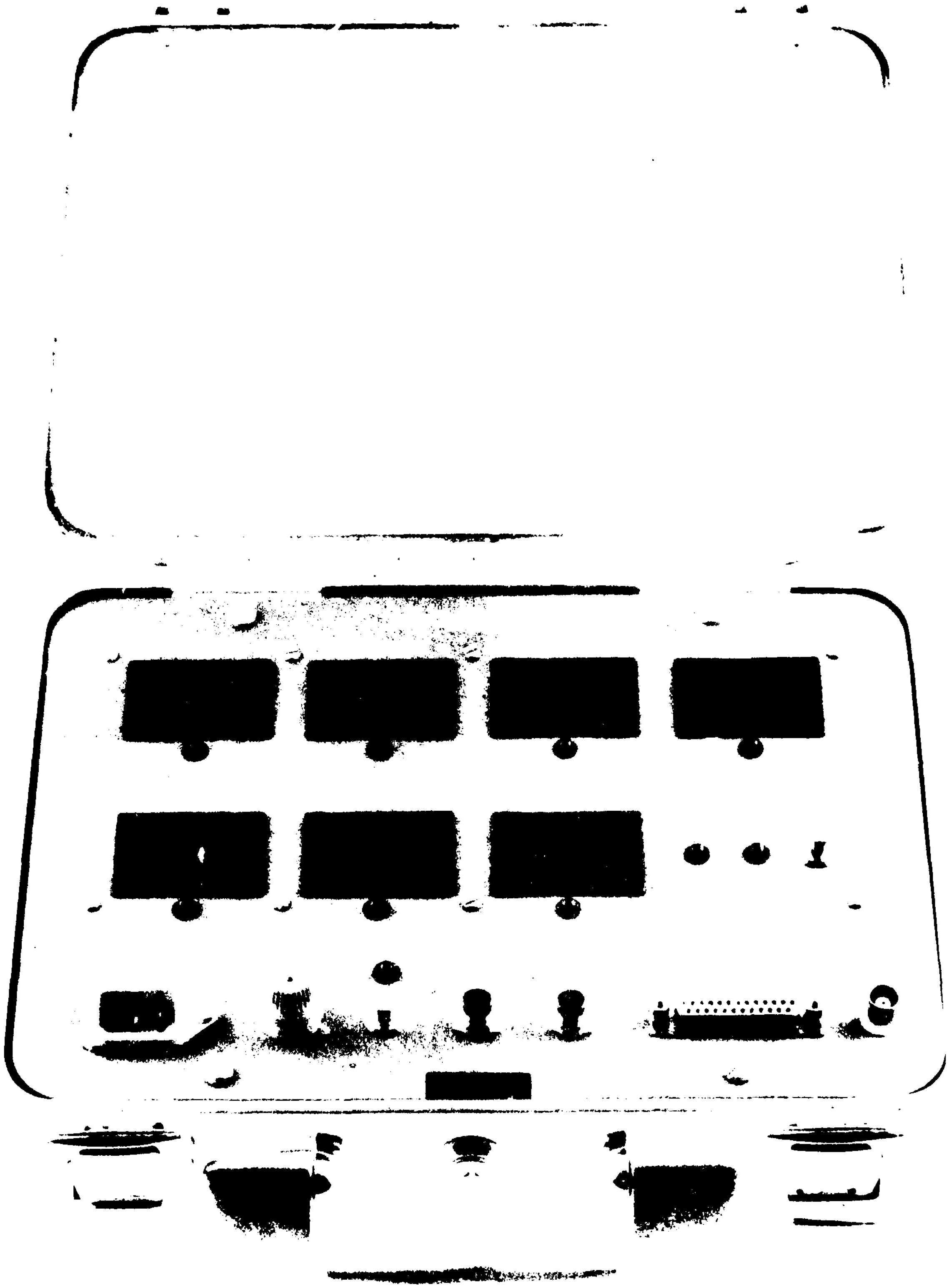


Figure 6 AGC Console

Although the booms could not be deployed before launch to determine their deployment characteristics, a linear potentiometer monitor circuit was designed into their mechanical drive train by the manufacturer to monitor the deployment progression. With known potentiometer resistance values, monitor circuits were designed to give telemetry values of +3V stowed and -4V deployed. In flight, the monitor circuit noted the fore dipole deployed in 4.5 seconds and the aft dipole deployed in 6.0 seconds.

3.3 MAIN ELECTRONICS PACKAGE

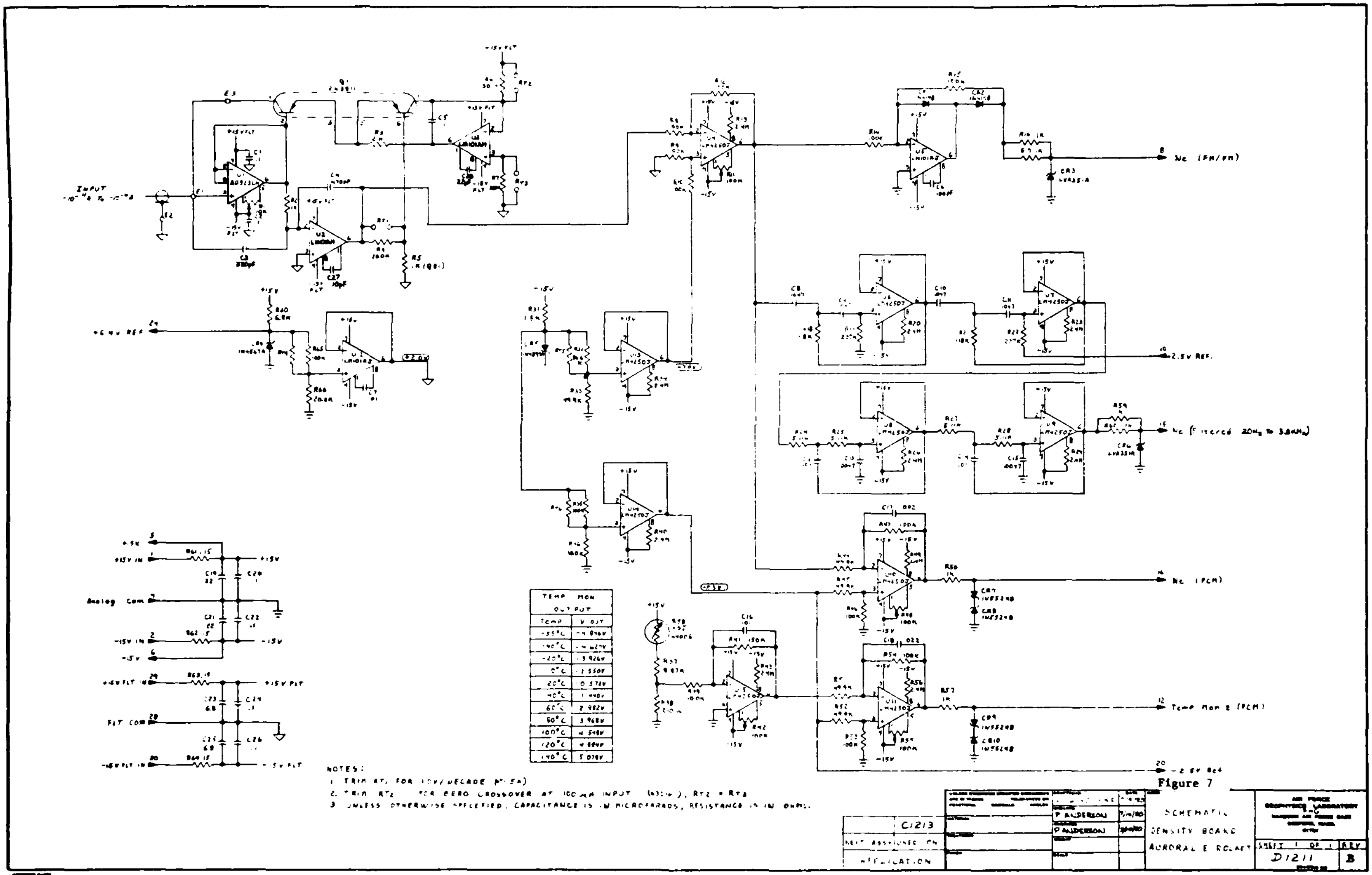
As shown in Figure 2, the MEP unit consisted of a mechanical housing, four printed circuit cards, and a dc to dc power converter (not visible) located in the base of the unit. Behind the front connector plate there was an interconnecting harness which provided electrical connections internally and externally. Externally, the MEP was connected to the boom assemblies, AGC unit, +28 volt battery pack, and a telemetry system.

The mechanical housing used for the MEP was the DMSP satellite SSI/E engineering test model (ETM). This housing required only one alteration which involved enlarging one connector slot on the front connector plate. Modifications to the built-in dc to dc power converter were more extensive. The ± 15 volt regulated secondary current limit was redesigned to yield an output of ± 60 mA. An unregulated ± 15 volt floating secondary was redesigned to incorporate a regulator circuit for sourcing an electrometer circuit. Also, several regulated off-set supply lines were designed into the secondary of the converter. All unused secondary circuit modules were removed for reliability and weight reasons.

The processing circuits were designed under the previous contract, F19628-77-C-0122. Under the present contract, the circuits were developed and finalized and then designed onto the four printed circuit (PC) boards. The schematic shown in Figure 7 is of the top PC board which processed the density signals. A logarithmic electrometer (U1, U2, U3, and Q1) was used on the input to change the electron current signals into electron voltage signals. With the logarithmic electrometer referenced to a +2 volt bias (U12), the electrometer output had to be level shifted (U4) with respect to the telemery system common. Operational amplifier (op amp) U13 is used for shifting the log electrometer output scale and op amp U14 is used to shift the PCM data output lines. Buffers U5 and U10 are used for driving electron density (N_e) signals to the FM/FM and PCM data lines respectively. Op amps U6 through U9 combined to form a four-pole bandpass filter which limited ac signals between 20 Hz and 3,800 Hz. These ac output signals were sent to the AGC unit. Op amps U15 and U11 formed a temperature circuit which was connected to a PCM telemetry data line.

The second board down in the PC stack was the electrometer board whose schematic is shown in Figure 8. Input signals from the boom sensors (A1, A2, B1, and B2) are connected to the electrometer amplifiers (U1 through U4 respectively). From these electrometer outputs, difference amplifiers U7, U8, U9 yield the vector electric field measurements which are buffered on the difference board and are also connected to the filter PC board. Sensor A1's electrometer output (U1) was offset (U6) and buffered (U5) to drive a PCM data line. Also located on this board were the two boom deployment monitor circuits (U10 and U11) which were connected to PCM data lines. Another temperature circuit (U12) was located on this board and was also connected to a PCM data line. Op amp U13 formed an offset voltage for the filter circuits.

The third board down in the PC stack was the difference amplifier board as shown in the schematic in Figure 9. Difference signal (A1-A2) was buffered into low (U3) and high (U4) gain signals which were connected to PCM data lines. The (A1-A2) difference signal was also offset (U1) and buffered (U2) to form the Ex signal which was connected to an FM/FM data line. The (A_s-B_s) and the (B1-B2) signal lines were also buffered (by U5, U6 and by U7, U8, respectively) developing buffered signals into low and high gain data lines which were connected to the PCM telemetry unit.



TEMP MON OUTPUT	
TEMP	V OUT
-55°C	-4.896V
-40°C	-4.629V
-20°C	-3.926V
0°C	-2.550V
20°C	-0.572V
40°C	1.440V
60°C	2.982V
80°C	3.968V
100°C	4.548V
120°C	4.884V
140°C	5.078V

NOTES:
1. TRIM RT1 FOR 1 V/DECADE (PT. 5A)
2. TRIM RT2 FOR ZERO CROSSOVER AT 100 μA INPUT (+3:1 V), RT2 = RT3
3. UNLESS OTHERWISE SPECIFIED, CAPACITANCE IS IN MICROFARADS, RESISTANCE IS IN OHMS.

Figure 7

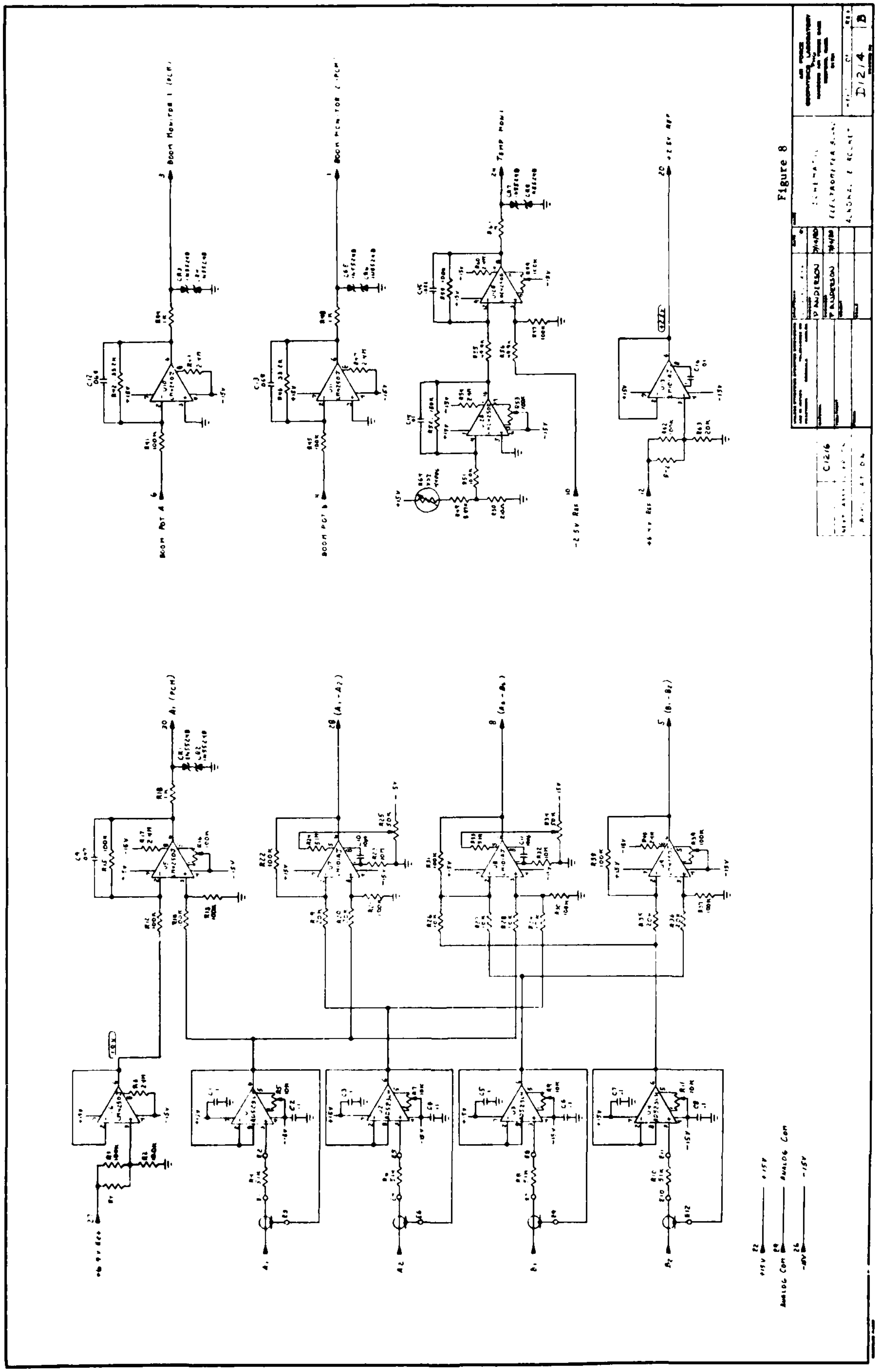


Figure 8

On the bottom of the PC stack was the filter PC board whose schematic is shown in Figure 10. Located on this PC board were three bandpass filters. Op amps U1 through U4 limit the (A_s-B_s) signal to between 10 Hz and 6,800 Hz; op amps U5 through U8 limit the (B1-B2) signal to between 20 Hz and 2,000 Hz; op amps U9 through U12 limit the (A1-A2) signal to between 40 Hz and 22,000 Hz. These three filtered ac signals were connected to the AGC unit.

A new interconnection harness was designed for interfacing the PC boards, power supply, and external connectors. The interconnection diagram is shown in Figure 11.

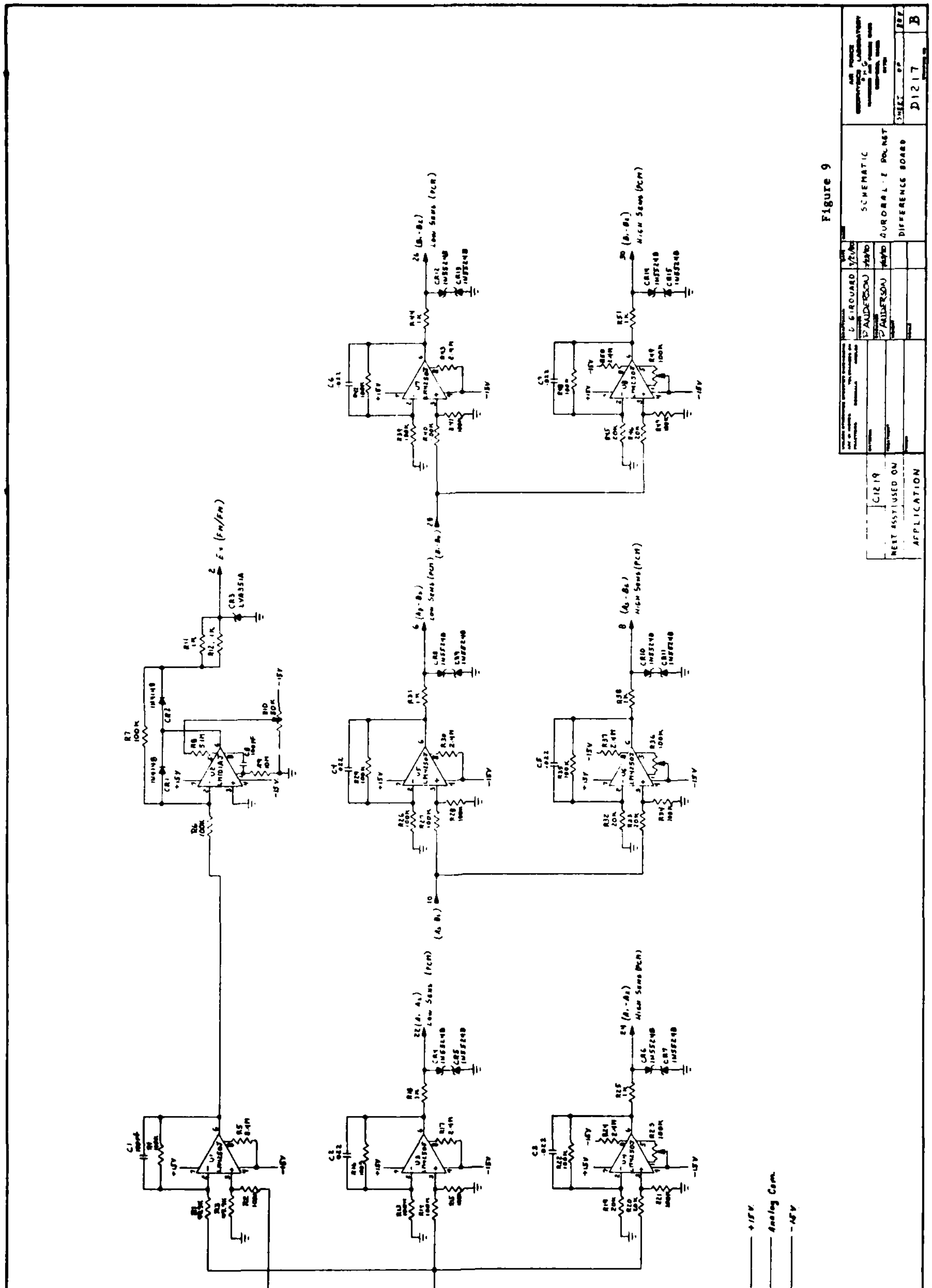
3.4 AUTOMATIC GAIN CONTROL UNIT

The automatic gain control (AGC) unit was purchased under the previous contract, F19628-77-C-0122. This unit received four ac signals (N_e, A1-A2, A_s-B_s, and B1-B2) from the MEP unit. These signals were constantly sampled and the gain was automatically adjusted to maintain a constant ac analog on the four output ($\Delta n/N$, ΔEx, ΔEz, and ΔEy) data lines. Gain status of each of the four data channels used was updated each second and formulated into an output serial digital data stream as shown in Figure 12 (3 of the 7 available data channels were not used). These outputs were connected to the FM/FM telemetry section. Power for this unit was provided by the AFGL rocket group from $\pm$18 volt battery packs.

3.5 GROUND SUPPORT EQUIPMENT

Ground support equipment was designed and developed under this contract. The MEP was a free running unit which received power from a battery eliminator, processed ac and dc signals from sensor simulators and sent signals to either the AGC unit or to the rocket telemetry system. These MEP interfaces were integrated by designing and fabricating a passive chassis. This chassis provided jacks for the power leads, BNC connectors for the input signals, BNC connectors for the telemetry data points, and a Cannon connector for interfacing with the AGC unit.

The AGC Console (Figure 6) was designed to operate off the 120 volt ac power line and display the serial digital data from the AGC data line of the AGC unit. Data from the AGC line was decoded and displayed as a gain number (0 = no gain, 11 = maximum gain) by a 1½-digit seven-segment display for the appropriate data channel. The consoles' front panel has two warning LED indicators, one for a bit frame error (BTFR) and the other for a word frame error (WDFR). Operation of the console required only the depressing of the reset button. The circuitry then looked for the sync word (all ones's). This was confirmed by the WDFR LED indicator turning on with the reset command and turning off when the sync word was received. Also, with the reset command, the data channel 1½-digit displays would blank and then begin to fill with data after the sync word was received.



SCHEMATIC
DIFFERENCE BOARD
D1217
B
G. GIROUARD
D. ANDERSON
C1219
NEXT ASSY USED ON
APPLICATION
+15V
Analog Com.
-15V

Figure 9

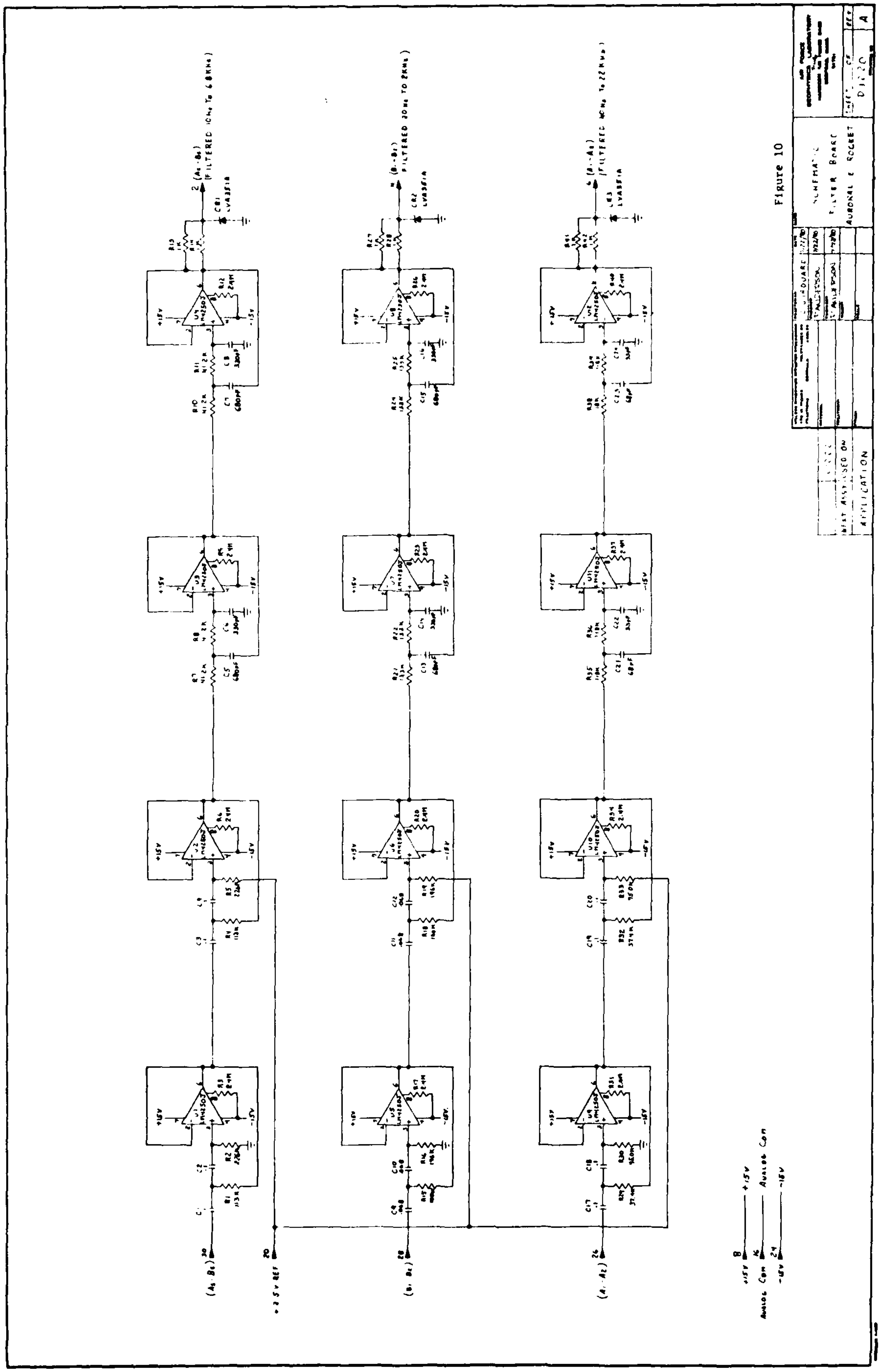


Figure 10

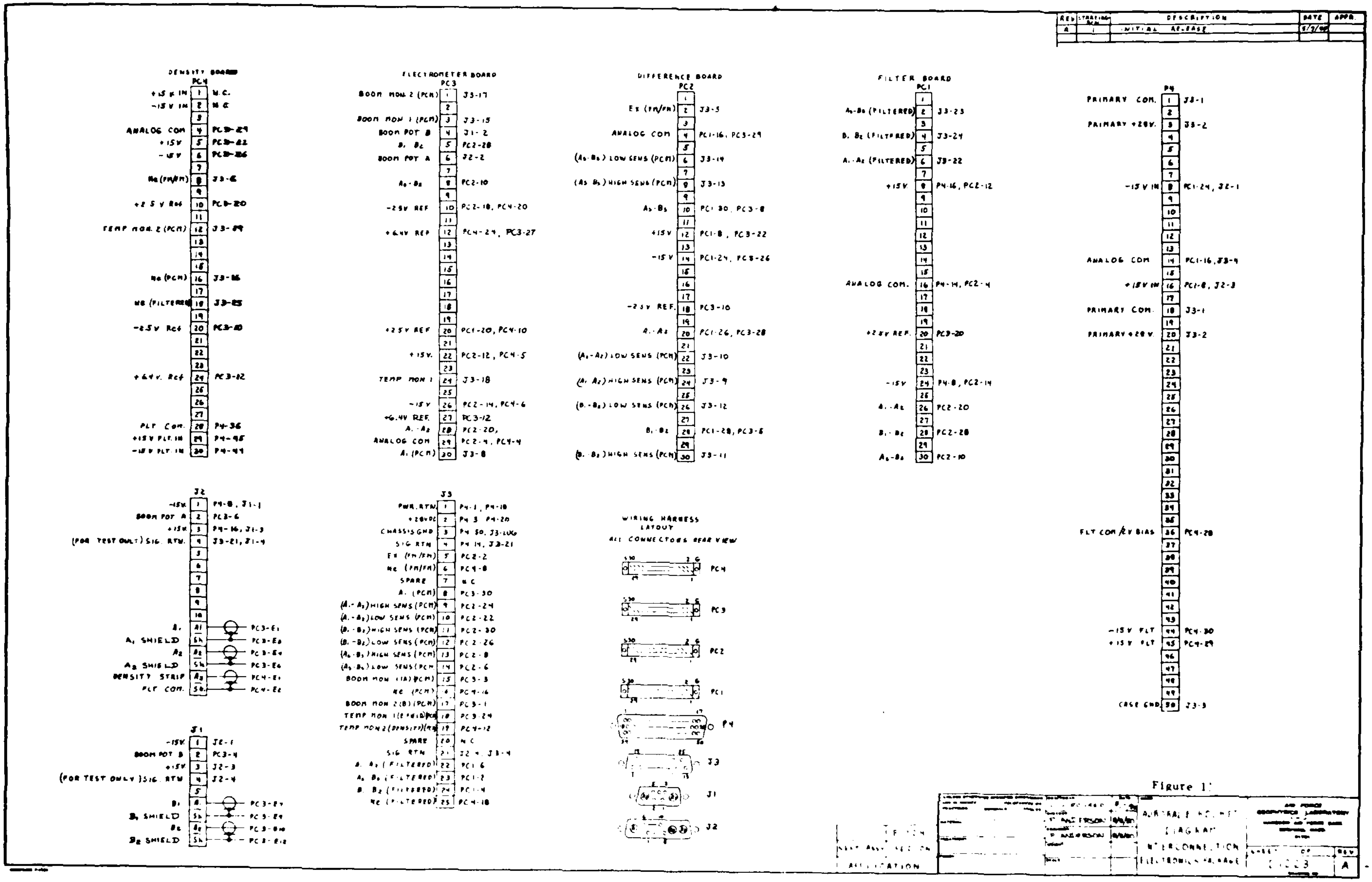

DENSITY BOARD
PC4
ELECTROMETER BOARD
PC3
DIFFERENCE BOARD
PC2
FILTER BOARD
PC1
P4
J2
J3
J1
WIRING HARNESS
LAYOUT
ALL CONNECTORS REAR VIEW
INITIAL RELEASE
INTERCONNECTION
ELECTRONICS PACKAGE

Figure 1

SERIAL TELEMETRY DATA FORMAT

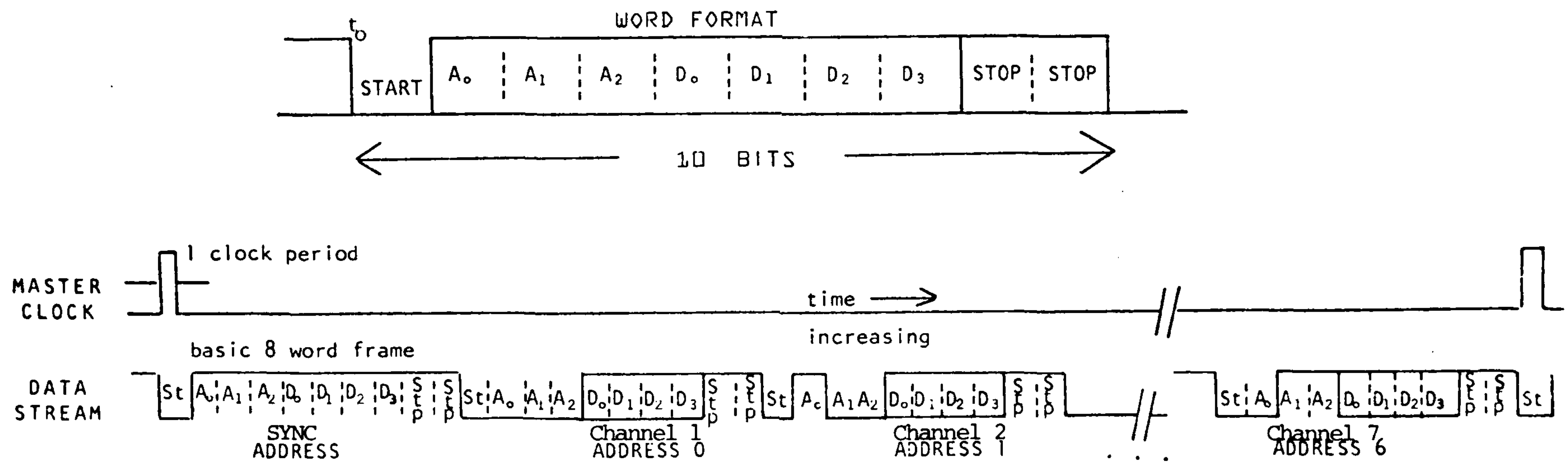


Figure 12 Serial Telemetry Data Format

The AGC Console was designed in three sections in order to be easily servicable. Section one contained all of the electronic circuitry located on a wire wrap board as shown in the schematic in Figure 13. Section two contained the display components mounted on a vector board as shown in the schematic in Figure 14. Section three contained the power supply and the front panel components as shown in the schematic in Figure 15.

The AGC console was initially debugged with the aid of the Tektronix microprocessor development system (MDL) and a bench top TI 990 microcomputer. Table 1 shows the console debugging software written for the TI 990 and stored on a Tektronix MDL floppy disc. With this program , all of the console's characteristics were checked automatically when the console received a test serial data stream from the TI 990.

4. INTEGRATION SUPPORT

The above system was supported at AFGL during the debug, burn-in, calibration, integration, and vibration phases. Both authors traveled to Poker Flat Research Range in Fairbanks, Alaska, to support integration and launch preparations.

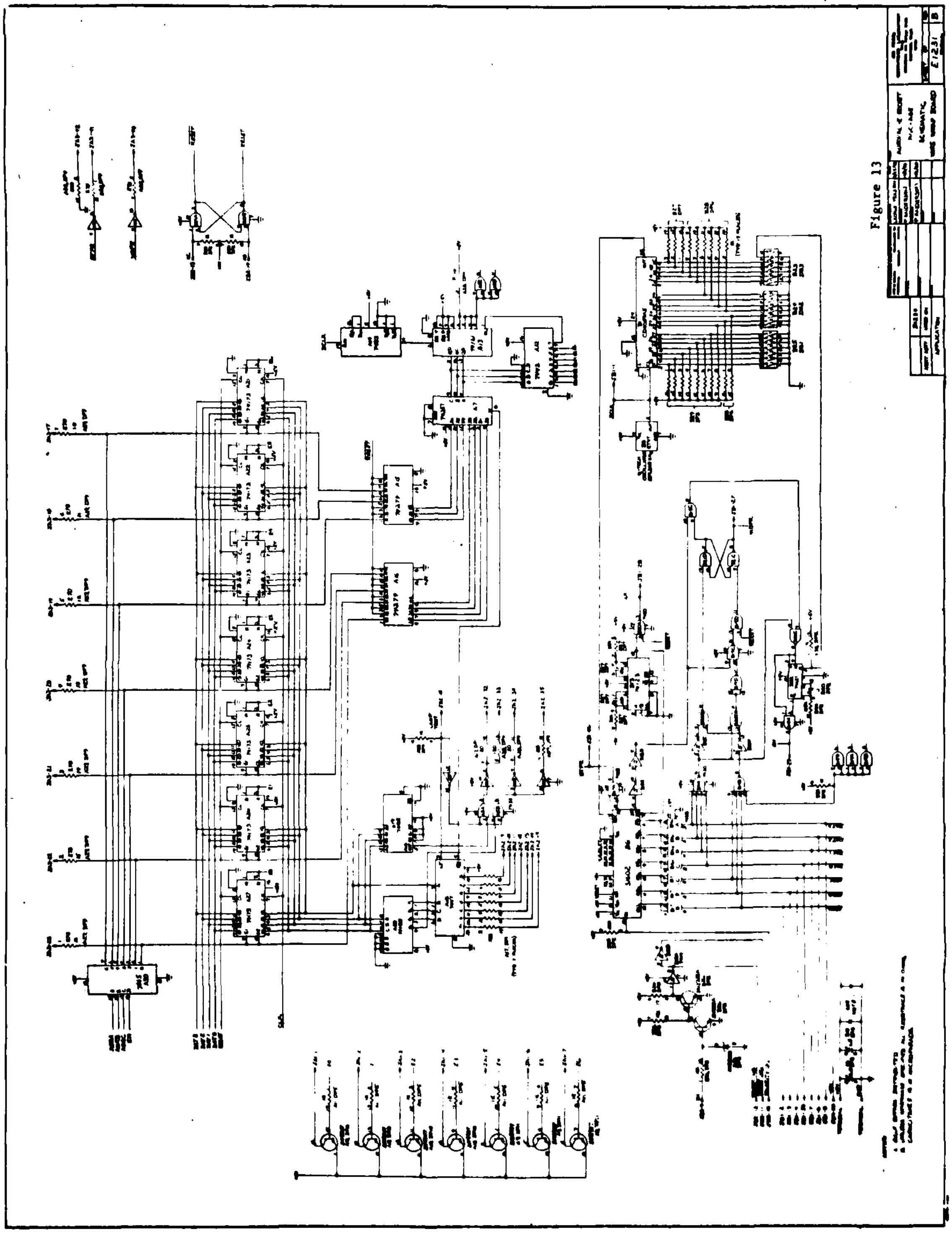


Figure 13

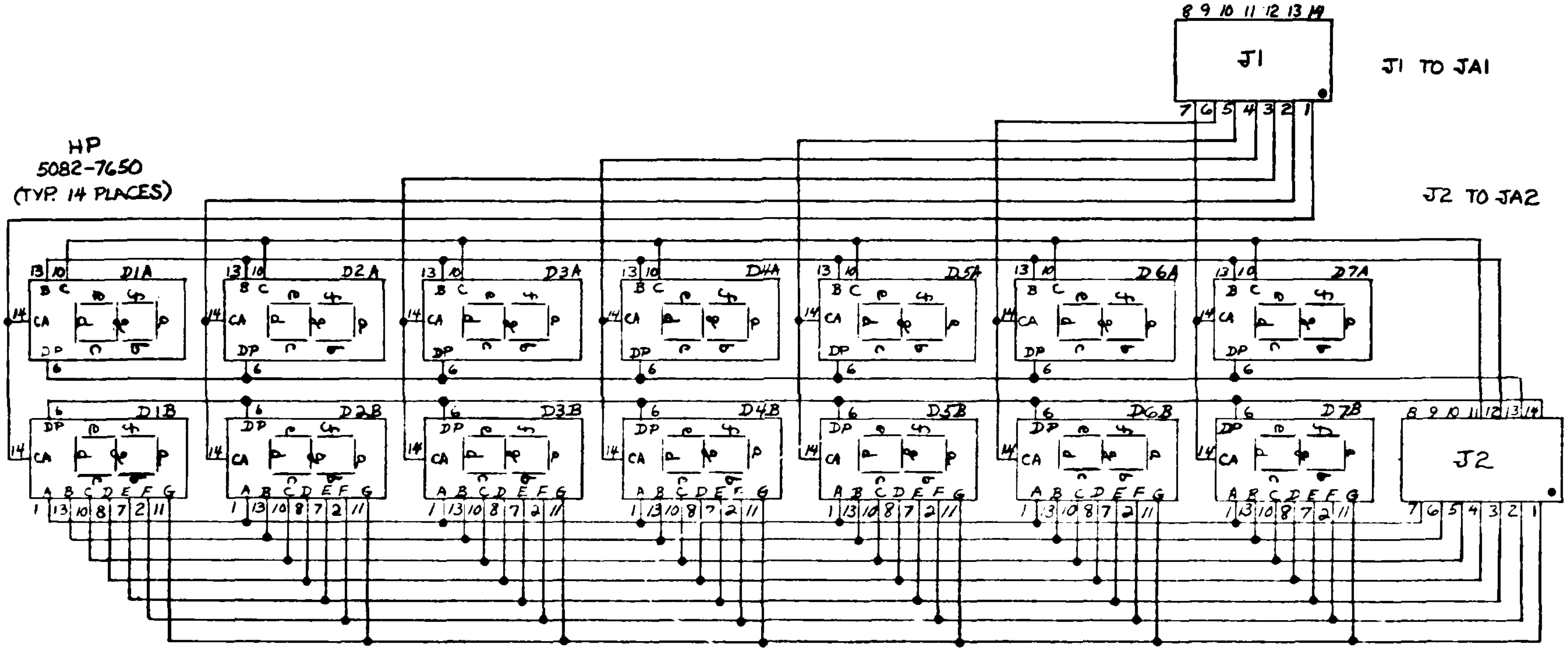


Figure 14

	B1234
NEXT ASSY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON FRACTIONS. DECIMALS. ANGLES

MATERIAL

TREATMENT

FINISH

		DATE
DRAFTSMAN	GEORGE TEKEYAN	8/27/80
CHECKER	P. ANDERSON	9/30/80
ENGINEER	P. ANDERSON	9/30/80
WEIGHT		
SCALE		

NAME

AURORAL-E ROCKET
AGC-AGE
SCHEMATIC,
DISPLAY BOARD

AIR FORCE
GEOPHYSICS LABORATORY
PHG
HANSCOM AIR FORCE BASE
BEDFORD, MASS.
01731

SHEET OF	REV
B1232	A

DRAWING NO

MAKEPEACE P-1899

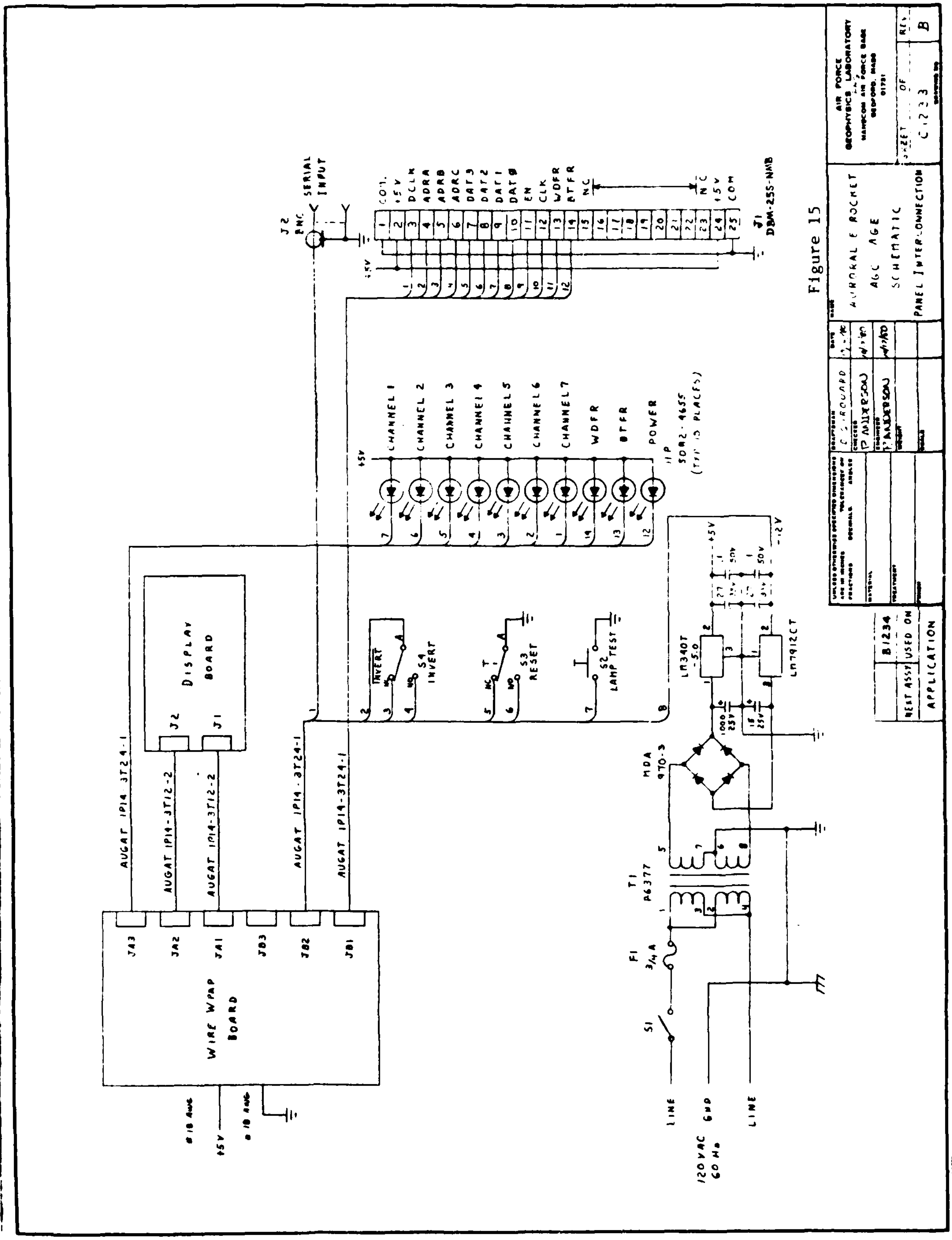

AIR FORCE GEOPHYSICS LABORATORY
HANSCOM AIR FORCE BASE
BEDFORD, MASS
01731
AURORAL E ROCKET
AGC AGE
SCHEMATIC
PANEL INTER-CONNECTION
WIRE WRAP BOARD
DISPLAY BOARD
SERIAL INPUT
CHANNEL 1
CHANNEL 2
CHANNEL 3
CHANNEL 4
CHANNEL 5
CHANNEL 6
CHANNEL 7
WDFR
BTFR
POWER
S4 INVERT
S3 RESET
S2 LAMP TEST
LM340T -5.0
LM7912CT
MDA 970-3
T1
F1 3/4 A
S1
LINE
GND
LINE
120 VAC 60 Hz
J1 DBM-25S-NMB
APPLICATION
USED ON
NEXT ASSY
81234
B
Figure 15

Table 1

Software - AGC Console Test

```
Tektronix    TMS 9900 ASM V3.3                                   Page    1

00001         F000          >          ORG   0F000H
00002 F000 0020          WS        BLOCK  32
00003 F020 02E0F000     >  ST        LWPI   WS
00004 F024 0202FB00                  LI     R2,0FB00H
00005 F028 02030073                  LI     R3,0073H
00006 F02C 02048200                  LI     R4,8200H
00007 F030 0205FF00                  LI     R5,0FF00H
00008 F034 020701F4                  LI     R7,01F4H
00009 F038 020C0180                  LI     R12,180H
00010 F03C 1D1F                      SBO    31
00011 F03E 3204                      LDCR   R4,8
00012 F040 3205                      LDCR   R5,8
00013 F042 3307                      LDCR   R7,12
00014 F044 02084200          L1      LI     R8,4200H
00015 F048 1E0D              L2      SBZ    13
00016 F04A 1F19              L3      TB     25
00017 F04C 13FE                      JEQ    L3
00018 F04E 1D0D                      SBO    13
00019 F050 1E14                      SBZ    20
00020 F052 0608                      DEC    R8
00021 F054 16F9                      JNE    L2
00022 F056 1E0D                      SBZ    13
00023 F058 3232                      LDCR   *R2+,8
00024 F05A 1D10                      SBO    16
00025 F05C 1F16              L4      TB     22
00026 F05E 16FE                      JNE    L4
00027 F060 1E10                      SBZ    16
00028 F062 0603                      DEC    R3
00029 F064 16EF                      JNE    L1
00030 F066 02068300                  LI     R6,8300H
00031 F06A 1D0E                      SBO    14
00032 F06C 3206                      LDCR   R6,8
00033 F06E 02090000                  LI     R9,0000H
00034 F072 3209                      LDCR   R9,8
00035 F074 1D10                      SBO    16
00036 F076 1F16              L5      TB     22
00037 F078 16FE                      JNE    L5
00038 F07A 04600080                  B      @80H
00039      FB00          >           ORG    0FB00H
00040 FB00 7F0001020304              BYTE   7EH,00H,01H,02H,03H,04H,05H,06H,08H,09H,0AH,0BH,0CH,0DH,0EH,10H
00040 FB06 0506080900A0B
00040 FB0C 0C0D0E10
00041 FB10 111213141516              BYTE   11H,12H,13H,14H,15H,16H,18H,19H,1AH,1BH,1CH,1DH,1EH,20H,21H,22H
00041 FB16 18191A1B1C1D
00041 FB1C 1E202122
00042 FB20 232425262829              BYTE   23H,24H,25H,26H,28H,29H,2AH,2BH,2CH,2DH,2EH,30H,31H,32H,33H,34H
00042 FB26 2A2B2C2D2E30
00042 FB2C 31323334
00043 FB30 353638393A3B              BYTE   35H,36H,38H,39H,3AH,3BH,3CH,3DH,3EH,40H,41H,42H,43H,44H,45H,46H
00043 FB36 3C3D3E404142
00043 FB3C 43444546
00044 FB40 48494A4B4C4D              BYTE   48H,49H,4AH,4BH,4CH,4DH,4EH,50H,51H,52H,53H,54H,55H,56H,58H,59H
00044 FB46 4E5051525354
```

```
Tektronix    TMS 9900 ASM V3.3                                   Page    2

00044 FB4C 55565859
00045 FB50 5A5B5C5D5E60              BYTE   5AH,5BH,5CH,5DH,5EH,60H,61H,62H,63H,64H,65H,66H,68H,69H,6AH,6BH
00045 FB56 616263646566
00045 FB5C 68696A6B
00046 FB60 6C6D6E707172              BYTE   6CH,6DH,6EH,70H,71H,72H,73H,74H,75H,76H,78H,79H,7AH,7BH,7CH,7DH
00046 FB66 737475767879
00046 FB6C 7A7B7C7D
00047 FB70 7E070700                  BYTE   7EH,07H,07H,00H
00048
```